Critical Infrastructure Software Security: A Maritime Shipping Study Case

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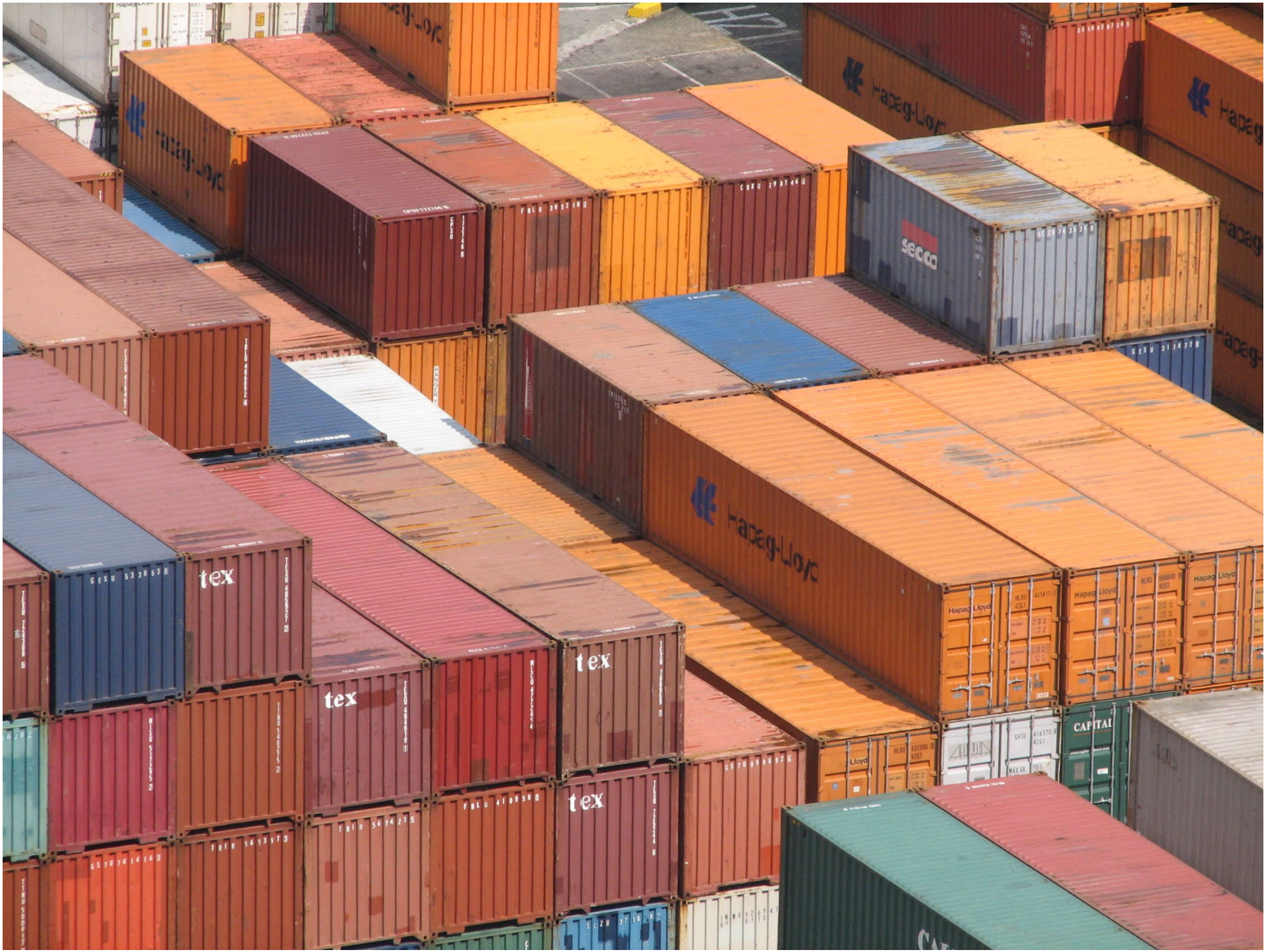
O'Reilly Velocity'18
Oct. 30-Nov. 2, 2018, London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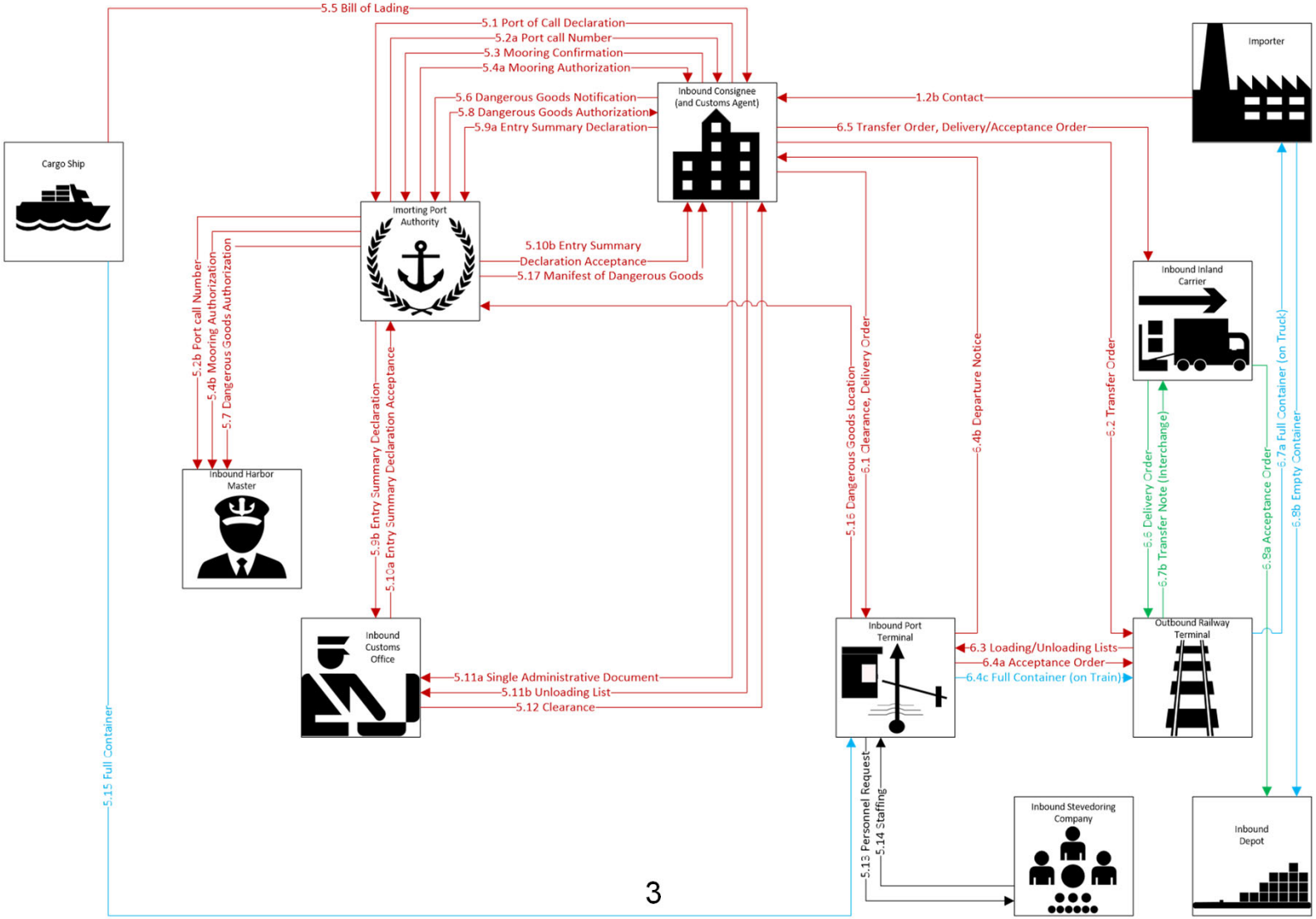
Context

Container terminals have a strong dependency on software.



Problem

- Computer systems that control maritime shipping are at risk due to the software they use.
- The software has vulnerabilities, and is therefore open to cyber-attacks.
- Terminal Operating Systems (TOS) and Port Community Systems (PCS) are especially critical.
- The cost of a disruption is at least $1 billion/day and has a cascade effect.

Good work in risk assessment, but …

- It's only a start.
- We need to focus on the software systems themselves (TOS, PCS).
- Only through an in-depth assessment of the software, can we be confident in its security.

We are addressing that challenge!

Our Work

- We started an effort to perform an in-depth vulnerability assessment of a TOS/PCS.
- First and critical step: have a software provider involved.
  - Social and psychological challenges to recognize the problem.
  - Surprisingly, we were given access to all their software technology.

How Did It Happen?

- **Our first observations,**

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- … to false steps,
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How Did It Happen?

- Our first observations,
- … to false steps,
- … to meetings with FEPORTS, Valencia,
- … to meetings with NOATUM, Valencia,
- … to contacts with a software provider and establishing trust,
- … to having access to the software and carrying out the actual assessment.

What Did We Do?

Looked for vulnerabilities in the TOS/PCS

What is a vulnerability?

"A vulnerability is a defect or weakness in system security procedures, design, implementation, or internal controls that can be exercised and result in a security breach or violation of security policy."

- Gary McGraw, *Software Security*

What Did We Do?

We only cared about vulnerabilities we could exploit.

What is an exploit?

"The process of attacking a vulnerability in a program is called exploiting."

The Art of Software Security Assessment

What Did We Do?

- Assessed a couple of software modules providing: Terminal Monitoring, Electronic Document Interchange (EDI) services, and movement of containers in the yard.
- Web-based system providing interface to current operation details of entire port, including gates, yards, ships, preadvice, containers, dangerous cargo, and related schedules and statuses.

How Did We Do it?

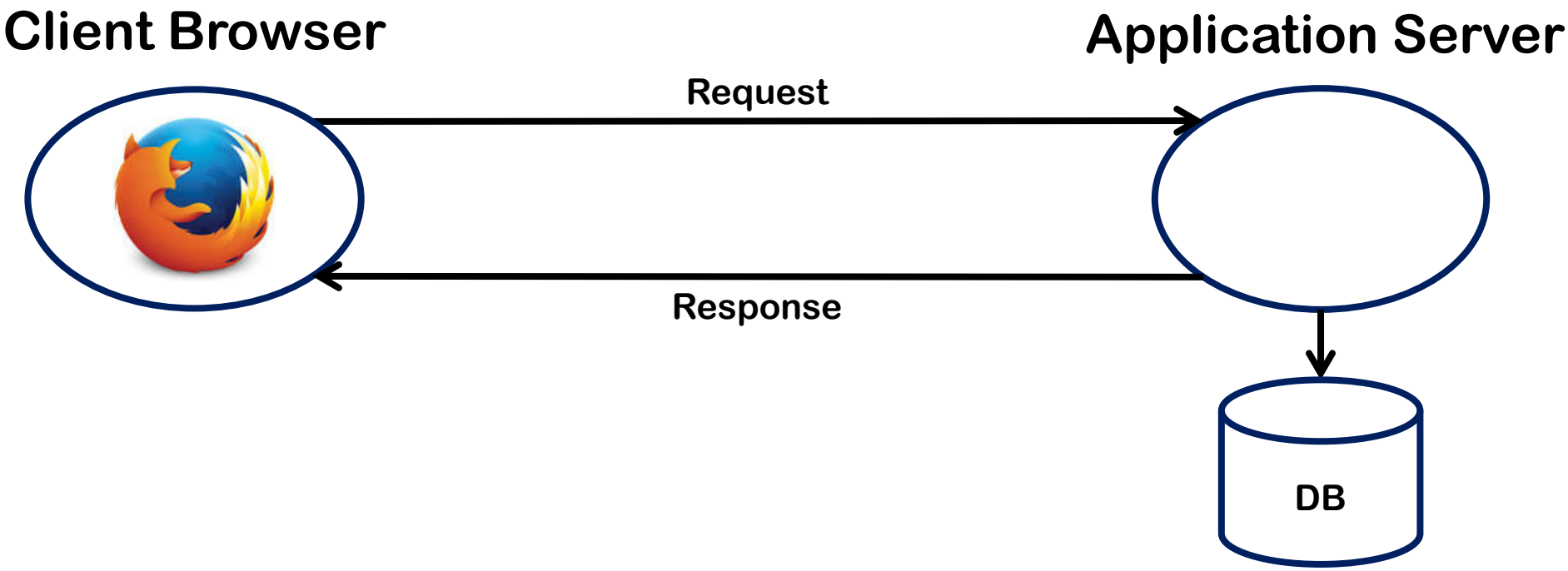
- First Principles Vulnerability Assessment (FPVA).
- While this takes time and effort, it's the only way to achieve strong security.
- FPVA Focuses on critical assets.
- Is not based on known vulnerabilities.

How Did We Do it?

FPVA:

- **Step 1:** Architectural Analysis
- **Step 2:** Resource Identification
- **Step 3:** Trust & Privilege Analysis
- **Step 4:** Component Evaluation
- **Step 5:** Dissemination of Results

How Did We Do it?



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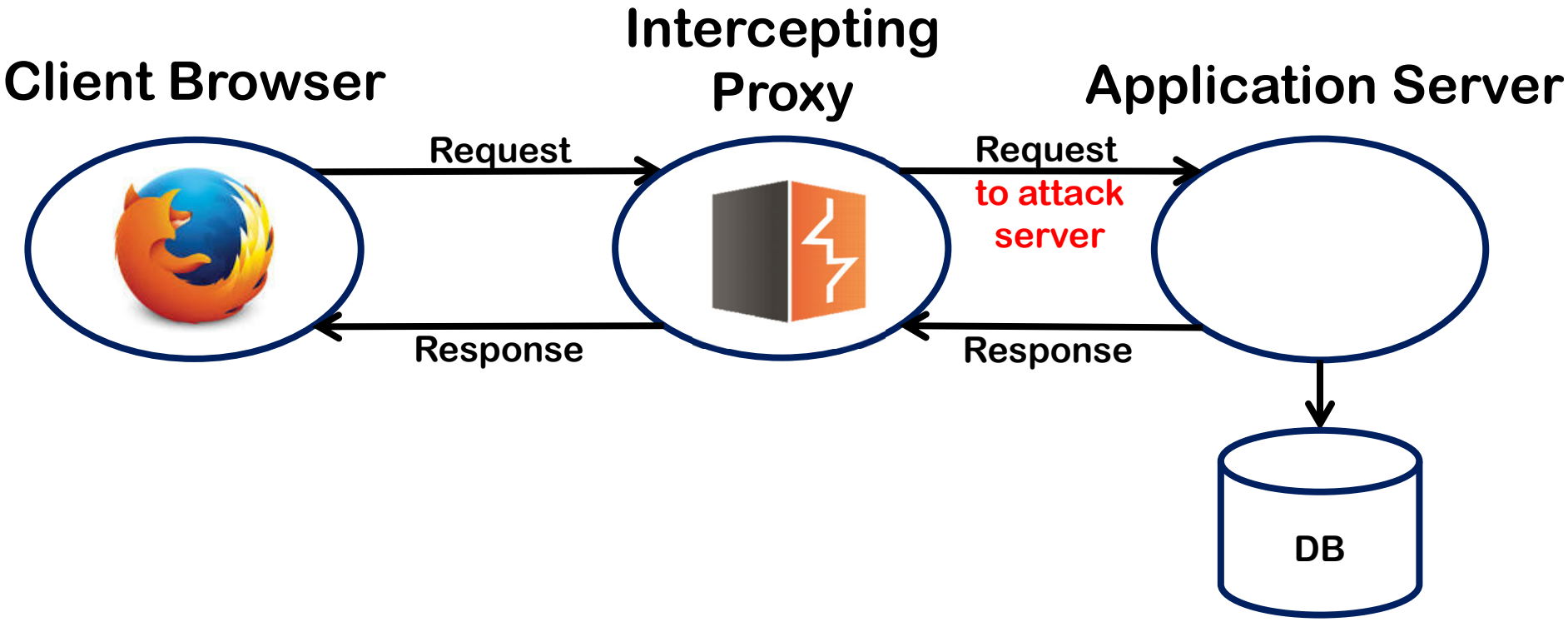
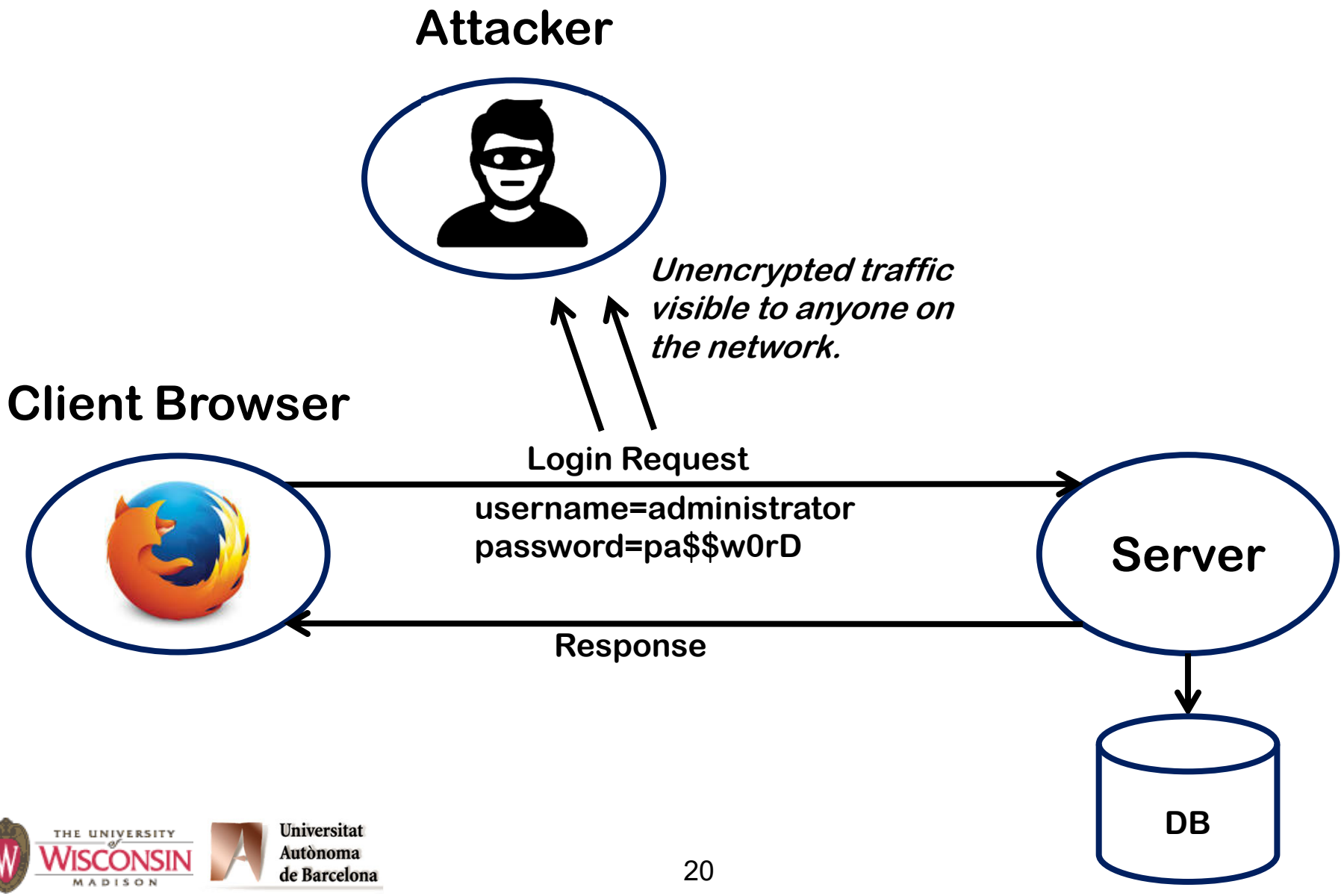


What Did We Find?

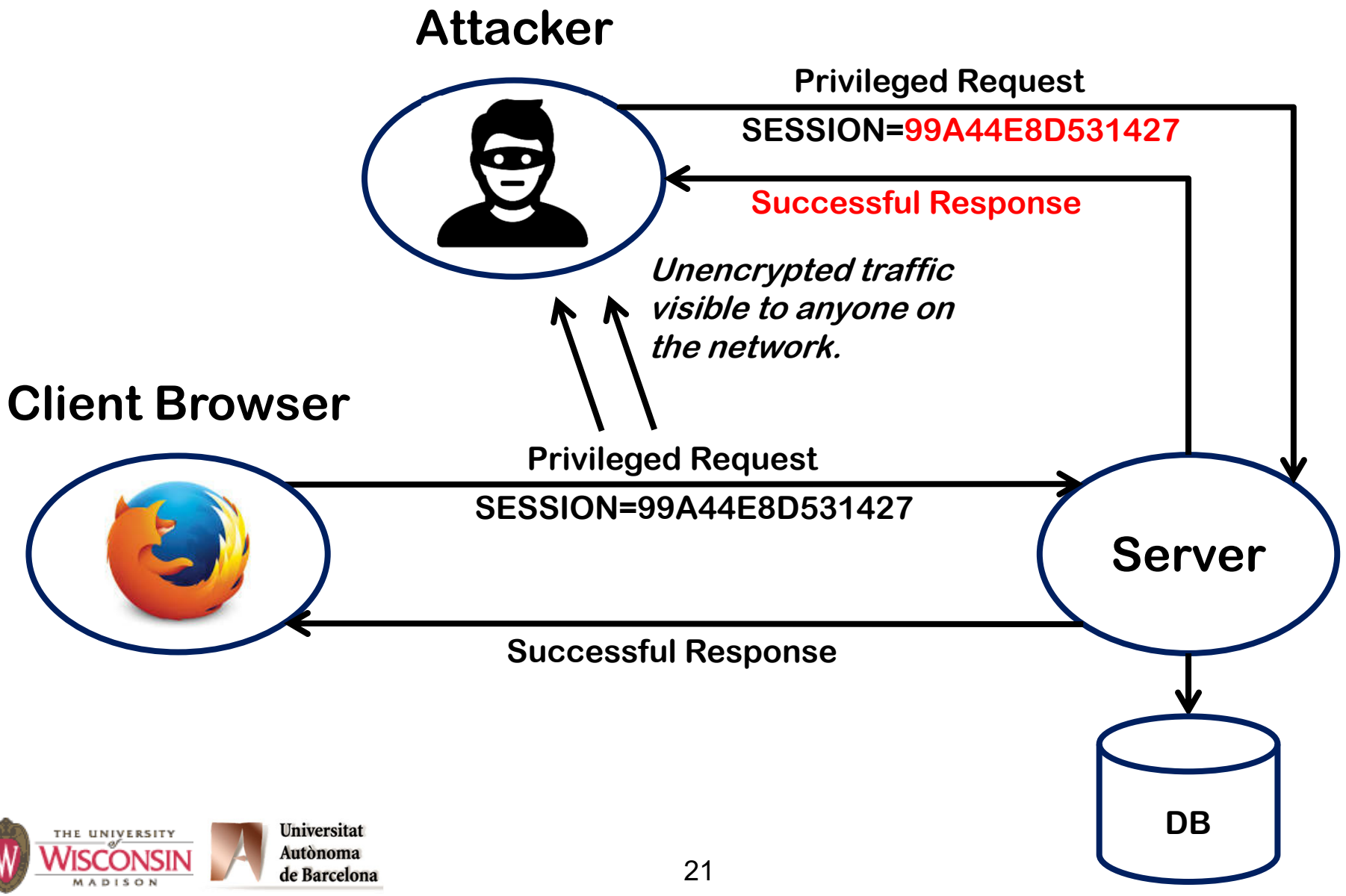
There were problems in the software:

1. HTTP traffic was not encrypted.
   - Session hijacking.
   - Password sniffing.
   - Observing the network traffic to gain info of the port's content without accessing the system.
2. Passwords were encrypted, not hashed.

Password/Traffic Sniffing



Session Hijacking

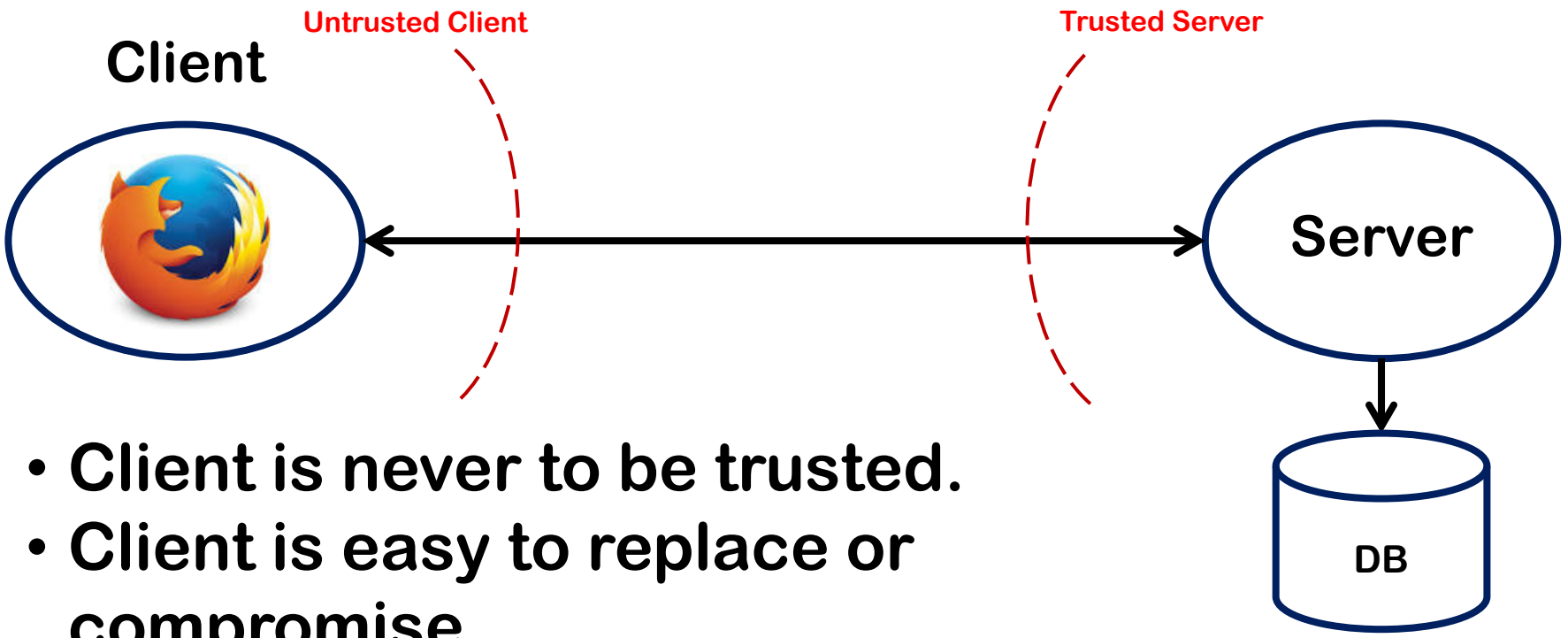


What Did We Find?

There were problems in the software:

3. Improper access to the database due to design issues, mostly validations only on the client side.
   - As a consequence any user could change any other user's password.
   - Trust boundary problem.
   - Design issues are expensive to fix.

Trust Boundary Violation



- Client is never to be trusted.
- Client is easy to replace or compromise.
- Any validation, authorization, or authentication on the client must be rechecked on the server.

Trust Boundary Violation

Client Requests Password Change for Currently Authenticated User

```
...
request.addParameter("username",
    currentUser.getUserName());
request.addParameter("newPass",
    form.getNewPasswordField());
httpClient.executeMethod(request);
...
```

Attacker Modifies Request Data

https://website.com/changePass	
username	~~realUser~~ admin
newPass	password1

Server Trusts the Username and Handles the Request

```
...
username = request.getAttribute("username");
newPass = request.getAttribute("newPass");
userDB.updateRowPassword(username, newPass);
...
```

What Did We Find?

There were problems in the software:

4. Use of vulnerable old version of some software frameworks.
   - *Software supply chain* issues: libraries, underlying OS, compilers.
   - Tools like OWASP Dependency Check, Dependabot, and Sonatype's Application Health Check can help.
   - Dynamic dependences and updates make this more difficult. Very hard issue.

What Did We Find?

There were problems in the software:

5. Users can modify and delete any files on the server machine.
   - Intercept a legitimate file request, then modify the request.
   - Improper validation allows path traversals.

Directory Traversal

C:\safedir\ ../Users/some_admin/important.doc

The client specifies the name of a file for the server to delete.

Client

Delete File Request

file="../Users/some_admin/important.doc"

Server

Successful Response

DB

Directory Traversal


```
C:\safedir\ ../Users/some_admin/important.doc
```

```
C:/
   Program Files/
   ProgramData/
   safedir/
      temp01.txt
      temp02.txt
      (...)
   Users/
      some_admin/
         important.doc
   Windows/
```

Directory Traversal

1. Request: `file="../Users/some_admin/important.doc"`

```
String path = request.getParameter("file");
// check for dir separators to prevent escape from safedir
if(path.contains(java.io.File.separator)){
    throw new PathTraversalException(path + " is invalid.");
}
path = "C:\\safedir\\" + path;
File f = new File(path);
f.delete();
```

2. Server deletes `C:\Users\some_admin\important.doc`

Separators predefined:

on Windows	java.io.File.separator = "\\"
on Unix	java.io.File.separator = "/"

Java File() constructor adapts pathname to underlying OS.

Then What?

- We suggested remediations to the software provider.
- We reviewed the code after the remediations.
- Several rounds of interactions were needed to implement the right fixes.
- They had an urgent need for training in software assurance and secure programming. Accomplished.

Closing Thoughts

- The TOS and PCS are large and complex pieces of software.
- No one has previously carried out an in-depth assessment of a TOS or PCS.
- An in-depth vulnerability assessment of the TOS and PCS is *essential* to prevent cyber-attacks.
- The vulnerabilities are there. Who will exploit them first?
- The involvement of software providers is essential.


Questions?